MECHANICAL BEHAVIOUR OF ACRYLONITRILE BUTADIENE STYRENE (ABS) SPECIMEN BY FUSED DEPOSITION MODELLING (FDM)

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Mechanical Engineering

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JANUARY 2019

ACKNOWLEDGEMENTS

Firstly, all the praise and gratitude to Almighty God for giving me good health and strength to complete my research successfully. Many people helped me throughout my research journey. No words to describe their contribution and time spent for helping me to complete my research. Sincerely, I would like to thank each one of them and apologies for any mistake or misbehaviour.

I am very grateful to express my sincere gratitude to my supervisor Dr. Mahendran Samykano for his germinal ideas, invaluable guidance, continuous encouragement and constant support. He has been my biggest inspiration throughout this research till my research study completed successfully. He never failed to help me whenever I faced problems with my research. He had always provided great ideas with immense knowledge and guidance from the beginning till to the end and also contribution in writing this thesis.

Moreover, I want to thank, Mr. Idris bin Mat Sahat for his guidance, suggestion, comment and co-operation in this project. Besides that, I sincerely want to thank laboratory staff of Mechanical Engineering Department and Manufacturing Engineering Department of UMP, for giving permission to use the testing instruments for my research analysis.

Most importantly, I acknowledge my sincere indebtedness and gratitude to my parents, Mr. V. Selvamani and Madam M. Puttharama for their love, dream and sacrifice throughout my life who give support for me financially and morally. Of course, I would like to acknowledge and sincerely thank all the other souls who have always been there for me, my fellow friends and special one too for encouraging motivationally and giving a lot of moral support throughout my project till it was fully accomplished.

ABSTRAK

"Fused deposition modelling" (FDM) adalah suatu teknologi pemprosesan yang amat penting kerana mempunyai banyak sumbangan dalam pelbagai sektor apabila dikombinasi dengan ABS. Aplikasi ABS dalam FDM boleh dimanfaatkan dalam fabrikasi model, prototaip, acuan dan peralatan. Tambahan pula, ia amat sesuai untuk aplikasi yang memerlukan kekuatan, kemuluran, kebolehkerjaan dan kestabilan haba. Walaupun begitu, ruang untuk penambahbaikan masih wujud untuk teknologi ini. Kekurangan informasi mengenai pengaruh peratus pengisian dan sudut pengisian di setiap lapisan terhadap ciri-ciri mekanikal produk ABS yang diproses melalui mesin FDM berkos murah adalah isu yang dikenalpasti untuk penyelidikan. Oleh itu tujuan penyelidikan ini ialah untuk menyediakan spesimen kajian dengan memanipulasikan peratus pengisian dan sudut pengisian dengan menggunakan teknik FDM, menyelidik ciri-ciri mekanikal produk ABS dengan melakukan ujian tegangan, ujian pembengkokan, ujian pemampatan dan ujian impak serta mengoptimumkan parameter pemprosesan melalui pendekatan statistikal. Oleh itu, penyelidikan ini yang merangkumi pemprosesan spesimen dan ujian tegangan, ujian pembengkokan, ujian pemampatan serta ujian impak terhadap spesimen yang dihasilkan dengan angka parameter yang berbeza. Analisa yang mendalam dikendalikan merangkumi pengajian data eksperimen, kajian statistikal, pengesahan dan optimasi parameter pemprosesan melalui "response surface methodology". Hasil penyelidikan menunjukkan peratus pengisian mempunyai kesan yang linear terhadap semua ciri-ciri mekanikal yang diuji. Manakala sudut pengisian mempunyai hubungan yang berubah dengan setiap ciri mekanikal. Dalam ujian tegangan, untuk modulus elastik dan kekuatan tegangan maksima, 0° mencapai tahap maksima manakala untuk "yield strength (0.2% offset)", 45° telah mencapai tahap maksima. Untuk ujian pembengkokan, 0° telah mencapai tahap maksima untuk kesemua ciri-ciri ujian pembengkokan. Manakala untuk ujian pemampatan, 90° telah mencapai tahap maksima untuk setiap cirinya. Akhir sekali, untuk ujian impak, 45° telah mencapai tahap maksima untuk kesemua cirinya. Tambahan pula, pengoptimuman yang dijalankan mencadangkan parameter yang sesuai untuk setiap ujian yang dapat menghasilkan tahap maksima secara kolektif atau individu. Parameter untuk ciri-ciri ketegangan dan ciri-ciri pemampatan yang optimum ialah 90° sudut and 99% kepadatan. Manakala, parameter optimum untuk ciri-ciri pembengkokan ialah 0° sudut dan 99% kepadatan. Akhir sekali, parameter optimum untuk ciri-ciri impak ialah 52.27° sudut dan 99% kepadatan. Hasil daripada penyelidikan ini, didapati bahawa peratus pengisian mempunyai hubungan linear dan sudut pengisian di setiap lapisan mempunyai kesan yang berbeza terhadap ciri-ciri mekanikal spesimen yang diuji dan ini dibuktikan melalui pengesahan data eksperimental melalui kajian statistikal. Sebagai cadangan utuk masa depan, parameter seperti ketebalan lapisan, ruang udara dan kelebaran penurapan boleh disertakan untuk kaji dengan lebih mendalam mengenai kesan parameter terhadap ciri-ciri mekanikal spesimen ABS yang diproses melalui teknik FDM.

ABSTRACT

Fused deposition modelling (FDM) is a prominent additive manufacturing technology that has various impactful contribution in numerous sectors when associated with ABS. Applications of ABS in FDM can be benefited in fabrication of models, prototypes, patterns and tools. Adding to that, it is very suitable for applications where strength, ductility, machinability and thermal stability are required. Simultaneously, there is still room for improvement to overcome the downsides found in this technology. Lack of information on the influence of infill percentage and raster angle combination, in the wide mechanical properties of ABS based low cost FDM machine specimens is one of the identified research gap. Thus, to coincide with the research gap, three objectives were set. The objectives were to develop ABS testing specimens by varying its' infill percentage and raster angle using FDM technique, to investigate the prepared ABS specimens' mechanical properties by performing tensile test, compression test, bending test and impact test and to develop an optimized printing parameter combination using statistical analysis. Hence, this research work comprises of printing test specimens using specific standards according to test conducted and implementation of mechanical characterization which includes tensile test, bending test, compression test and impact test of specimens printed with altered infill percentage and raster angle which were the selected varying printing parameters. Thorough analysis comprising experimental data evaluation, statistical evaluation and optimizations using response surface methodology were carried out to study in detail the effect of the selected printing parameters on the mechanical property of the ABS-based specimens. Outcome of mechanical test shows, the infill percentage demonstrates significant effect on all the mechanical properties tested. For instance, higher the infill percentage, the higher the value of the properties. Meanwhile raster angle has varying effects with properties tested. For tensile test, highest elastic modulus and ultimate tensile strength achieved with raster angle of 0° whereas highest yield strength (0.2% offset) was achieved with raster angle of 45°. For bending test, raster angle of 0° shows that it has important effect on the flexural properties since the highest value for properties were achieved at this raster angle. For compression test, the highest value for both compression strength and compression modulus were achieved when it is at 90° raster angle. For impact test, raster angle of 45° has the highest effect on the impact properties since the impact properties with this 45° raster angle achieved the highest value. Furthermore, completed optimization suggests the parameter for each test that would result in overall optimum mechanical properties and optimum individual mechanical properties. Parameters for optimum tensile properties and compression properties are 90° raster angle and 99% infill percentage. Meanwhile, parameter for optimum bending properties are 0° raster angle and 99% infill percentage. Finally, parameter for optimum impact properties are 52.27° raster angle and 99% infill percentage. Overall results of this research show that infill percentage has linear relationship with all the mechanical properties whereas raster angle has varying effect on the mechanical property of the specimens and it was proved by the validation of the experimental data using statistical evaluations. As a recommendation, parameters such as layer thickness, air gap and contour width also can be varied with infill percentage and raster angle to identify detailed effect of printing parameters on the mechanical property of printed specimens for the future improvement of the strength of the ABS based FDM specimens or products.

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LIST OF SYMBOLS

W_c	Width of gage
W_o	Width overall
L_o	Length overall
α	Alpha value

LIST OF ABBREVIATIONS

DNA	Deoxyribonucleic acid
RNA	Ribonucleic acid
PLA	Polylactic acid
3D	3-Dimensional
FDM	Fused deposition modelling
ABS	Acrylonitrile butadiene styrene
SAN	Styrene and acrylonitrile copolymer
ASTM	American Society for Testing and Materials
AM	Additive manufacturing
STL	Stereolithography
USB	Universal Serial Bus
SD	Secure Digital
WIFI	Wireless Fidelity
MOR	Modulus of Rupture
SLA	Stereolithography
SLM	Selective laser melting
SLS	Selective laser sintering
DLP	Digital light processing
EBM	Electron beam melting
LOM	Laminated object manufacturing
UTS	Ultimate tensile strength
AVE	Average
Coef	Coefficient
SE coef	Standard errors on estimation of the coefficients
DF	Degree of freedom
Adj SS	Adjusted sum of square
Adj MS	Adjusted mean of square

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